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Review of Methane Emissions and Sources from Natural Gas Operations

Virginia Department of Environmental Quality

Methane Leakage from Natural Gas Infrastructure
Ad Hoc Workgroup Meeting

Presented by:

Jim McCarthy, Innovative Environmental Solutions, Inc.

Richmond, VA

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Agenda

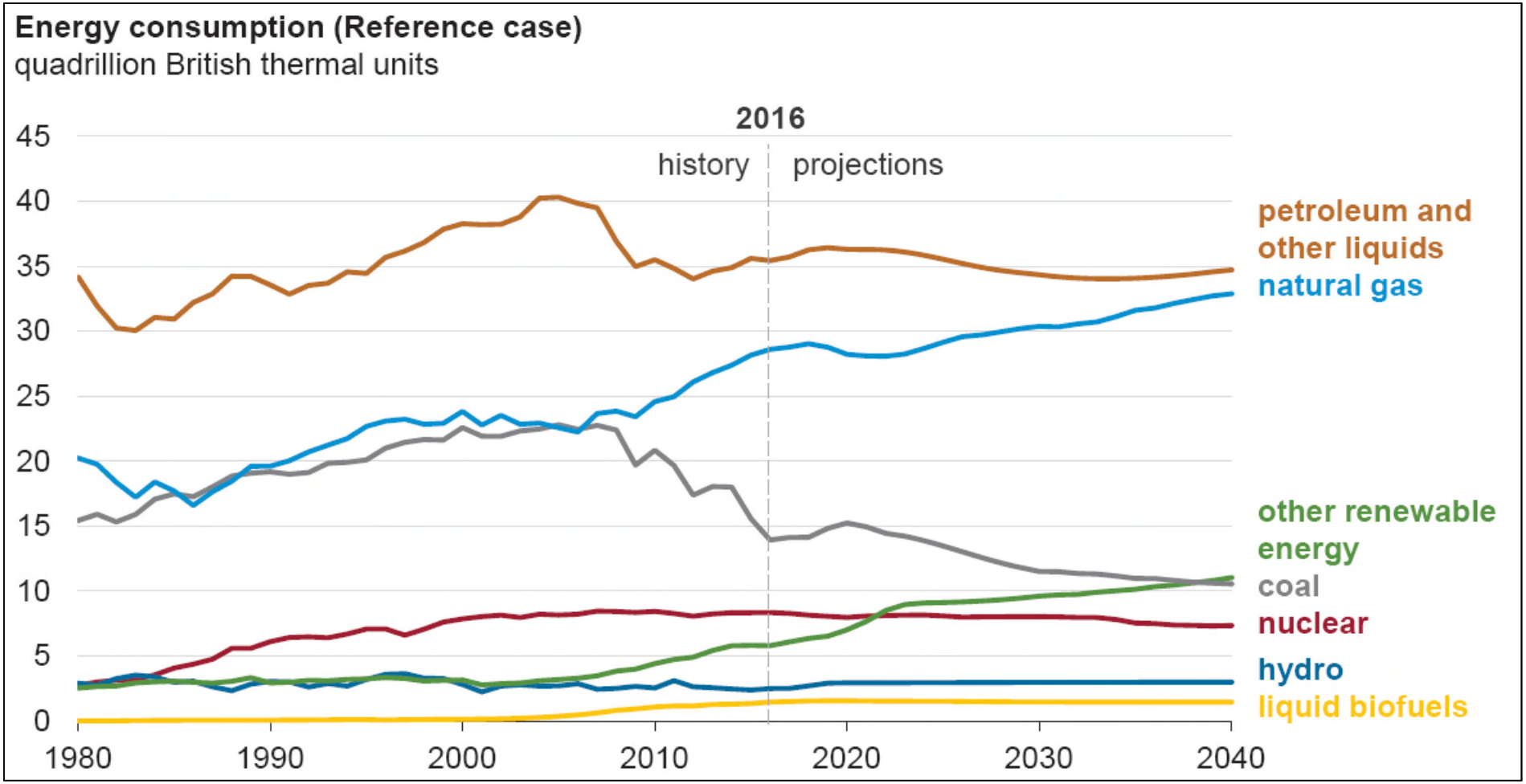
- Natural gas and U.S. energy use; VA implications
- Methane emission estimates from natural gas operations
  - » VA estimates from EPA GHG Reporting Program (GHGRP)
  - » Background on historical / other data sources
- Methane emission sources for transmission & storage (T&S) and distribution
- Overview of methane mitigation strategies for T&S and distribution
  - » Insights from GHGRP data
  - » EPA programs / regulations:
    - NSPS (Subpart OOOOa) for compressor stations
    - EPA Natural Gas STAR – e.g., Methane Challenge BMPs

Presentation Highlights

- **Natural gas use in U.S. and VA is growing and growth is projected to continue (e.g., supplant coal)**
  - » **Although gas use has grown, methane emissions from natural gas systems have decreased**
- **There are relatively few natural gas facilities in VA, so methane emissions are relatively small from natural gas operations (Distribution systems, ~ 20 transmission compressor stations)**
- **Improved understanding of CH_4 sources & emissions in recent years – e.g., from GHGRP data, other studies**
  - » **Sources and emissions by natural gas segment; GHGRP data is providing insight into emission priorities**
- **Voluntary efforts (e.g., Natural Gas STAR) and regulations have identified methane mitigation options**
- **For leak emissions, a few large leaks contribute most emissions**
  - » **Technology advances (e.g., leak quantification) may be imminent**
  - » **Convergence of emissions understanding and technology provide opportunities for smarter alternatives to reduce methane**

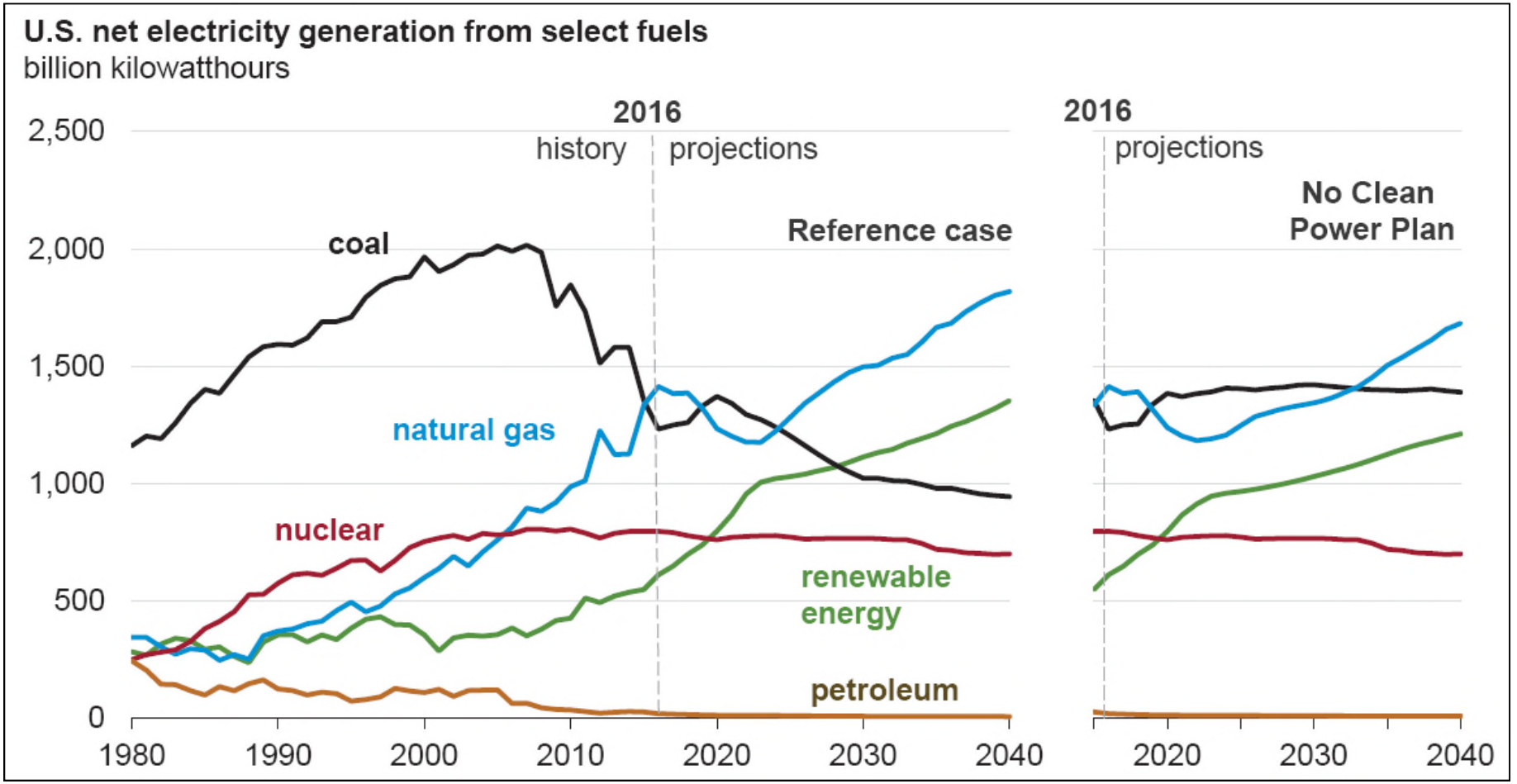
DOE EIA – U.S. Energy Consumption

- **DOE EIA projections – all uses (transportation, electricity, etc.)**



DOE EIA – U.S. Electricity Generation

- **DOE EIA projections for 2016 provided with and without Clean Power Plan**
- **2017 VA electricity: 11.9% coal, 49.2% gas, 33.8% nuclear**



VA Natural Gas Facts

- 1.3 million natural gas customers (1.2 million residential)
- Consumed ~552 BCF of natural gas in 2015 (~570 trillion Btu) with was 2.2% of U.S. consumption (AGA state gas facts)
  - 14% residential
  - 12% commercial
  - 57% electric power generation
  - 17% industrial / other
- VA natural gas market share for all electricity generation
  - https://www.eia.gov/electricity/data/state/ (Sept 2018 update)
  - 49.2% in 2017 (11.9% coal, 33.8% nuclear, 1.3% solar/biomass)
    - 72% growth in VA electric generation from 1990 to 2017
  - 23.3% in 2010 (34.9% coal, 36.4% nuclear , 1.1% solar/biomass)
  - 6.0% in 2000 (51.5% coal, 36.7% nuclear , 0.6% biomass)
  - 2.2% in 1990 (45.5% coal, 45.3% nuclear, 1.2% biomass)

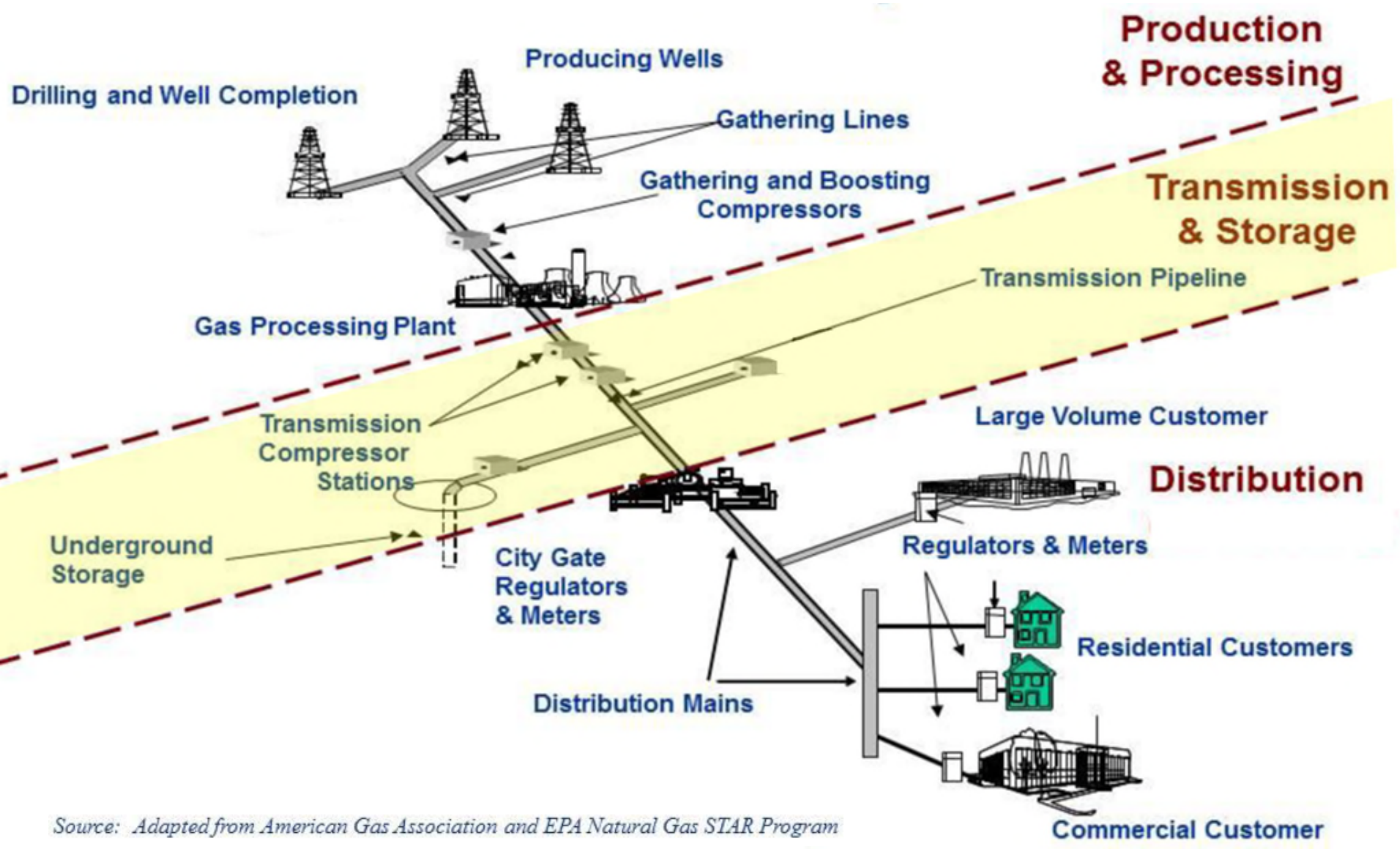
Natural Gas Operations: Methane Emissions Background

- **Pipeline natural gas is typically 90 – 96% methane**
  - **Balance is mainly ethane**
  - **Relatively low VOC content**
- **Historical estimates of natural gas industry methane emissions (e.g., EPA annual GHG inventory (GHGi), estimation protocols) primarily based on 1996 EPA-GRI report**
  - **For over 20 years, minimal new methane data was added**
  - **EPA GHGRP, other new studies include new measurement data for T&S operations**
- **Voluntary Natural Gas STAR program demonstrated reductions – mitigation identified by industry operators**
  - **STAR supplemented with Methane Challenge in 2016**
  - **Mandatory rules now evolving at federal and state levels**

Federal Programs: Chronology

- EPA-GRI report (15 vols) on NG industry methane emissions in 1996
- Annual U.S. GHGi has been prepared since 1997
  - » Time series of emissions by industry segment to 1990
- EPA Natural Gas STAR program: Voluntary reductions from natural gas systems since mid-1990s
  - » EPA introduced supplemental Methane Challenge program in 2016
- GHG Reporting Rule (GHGRP) since 2010 (combustion) and 2011 (add Subpart W methane leaks and vented emissions)
  - » Intent: Provide information to inform policy
  - » Most industries use emission factors or engineering estimates; T&S requires measurement of several key sources
- NSPS (Subpart OOOO) in 2012 affected oil and gas operations upstream of transmission: VOC rule with methane co-benefits
- Add methane to NSPS: Subpart OOOOa in June 2016 adds T&S

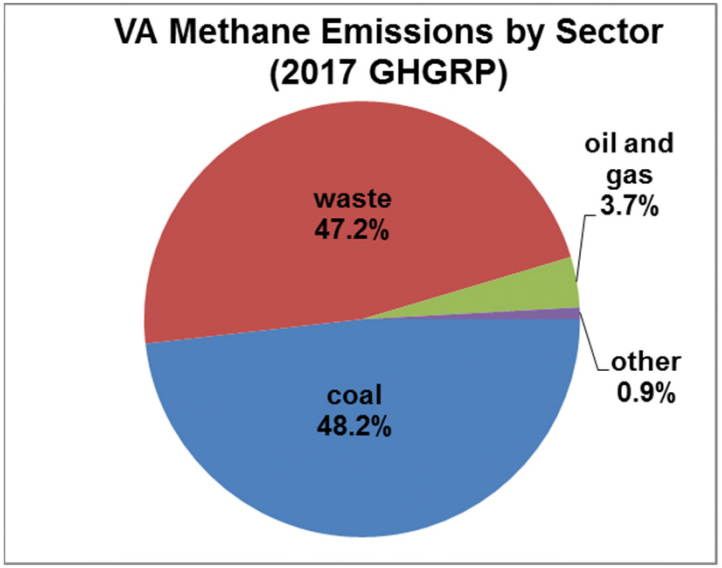
Natural Gas Operations: Industry Segments



Source: Adapted from American Gas Association and EPA Natural Gas STAR Program

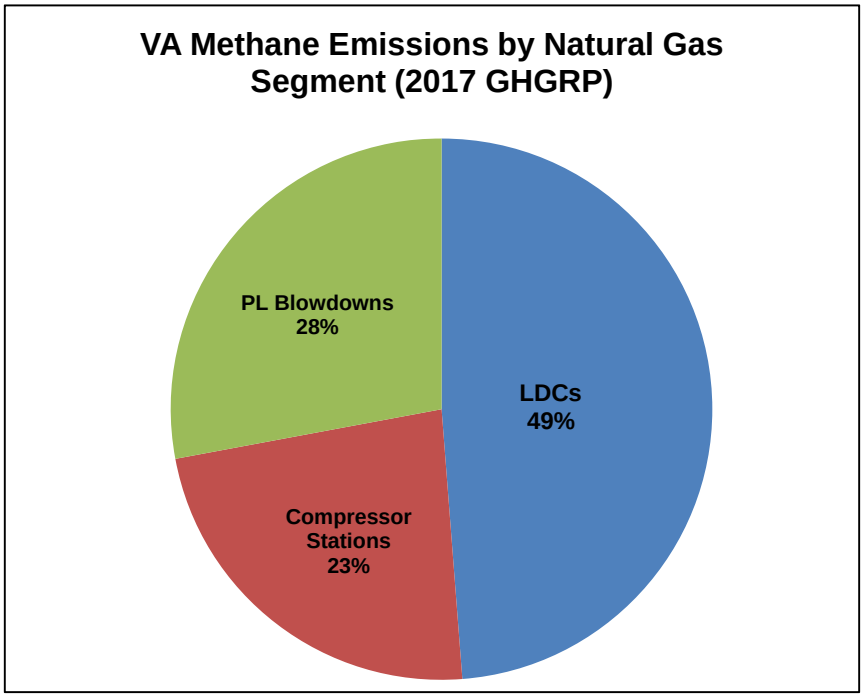
VA Methane Emissions and Natural Gas Operations

- Natural gas sector in VA (and thus emissions) is primarily comprised of transmission and storage (T&S), and distribution
  - » Minimal production (115 BCF in 2017, 0.3% of U.S. production)
- Approximately 20 T&S facilities in VA; EPA GHGRP (2017 data) includes 4 compressor stations, 4 LDCs
  - » Other compressor stations are smaller and/or low use so emissions did not exceed 25,000 metric ton reporting threshold
- Methane emissions are ~14% of VA GHG inventory (2017 GHGRP)
  - » 6 MM mt CO_2e CH_4 of 44 MM mt total
  - » VA methane mainly from coal and waste (landfills); 3.7% from gas ops
  - » In comparison, nationwide CH_4 ~10% of total; oil & gas is ~24% of methane



VA Methane Emissions by Natural Gas Segment

- **Natural gas segment 2017 methane emissions in VA ~232,000 metric tons CO_2e**
  - » **Roughly half of emissions from LDCs and half from T&S**
  - » **LDCs have typically not been regulated – reductions primarily from replacing gas mains – e.g., see Methane Challenge Best Management Practices (BMPs)**
  - » **Additional discussion follows on T&S emission sources and mitigation approaches**

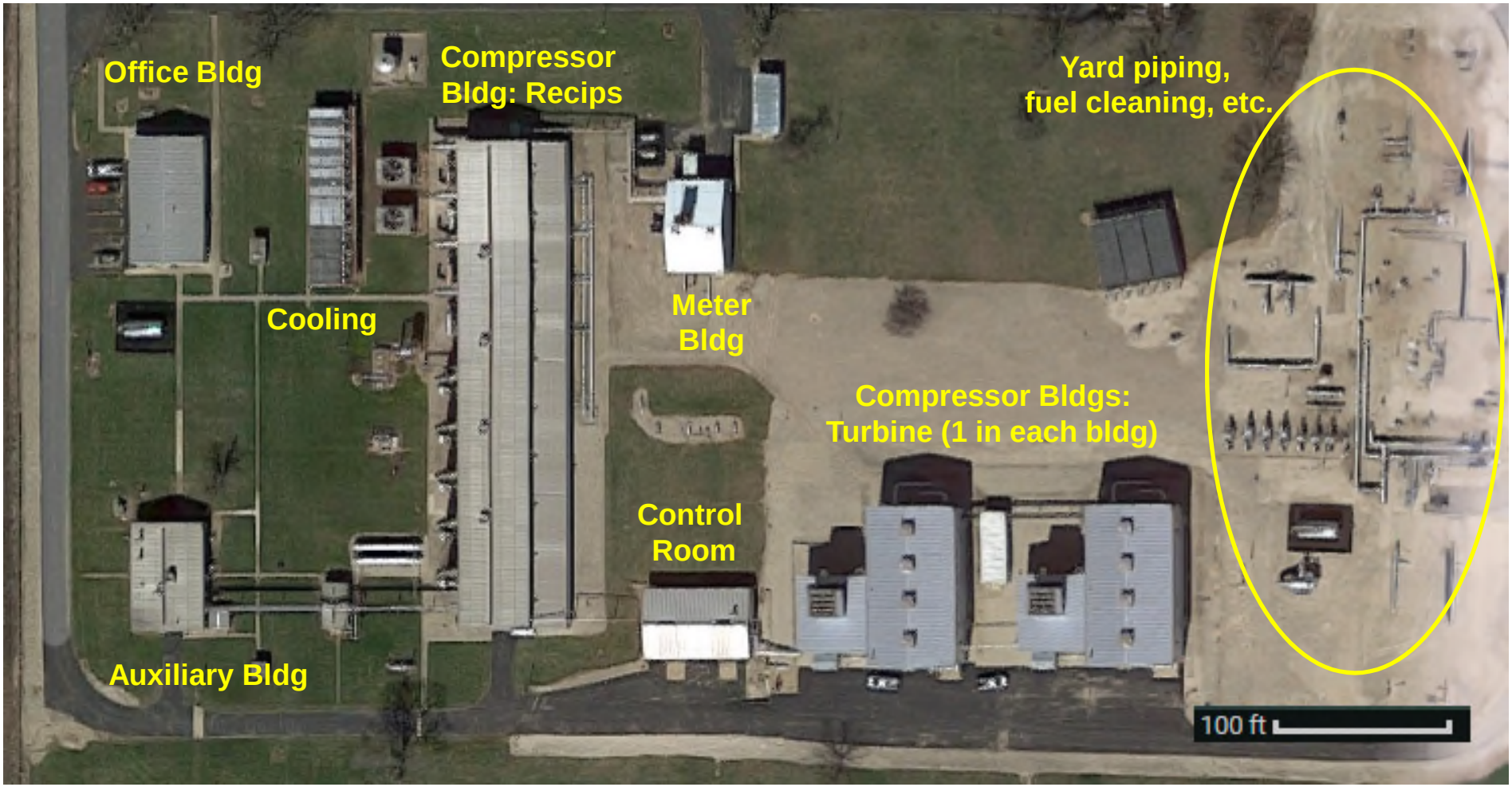


U.S. EPA GHG Reporting Program: Primary Methane Emission Sources

- **Onshore production segment reports 16 methane sources**
  - **Well-related venting (completions, recompletions, etc.)**
  - **Initial processing (e.g., remove H_2O) and compression at well**
  - **Storage tanks, pneumatic devices, leaks**
- **Gathering and boosting segment reports 10 sources**
  - **Pneumatics, processing, blowdowns, compressors, leaks**
- **Processing segment reports 6 sources**
  - **Processing, compressors, blowdowns, leaks**
- **Transmission compressor stations report 6 sources**
  - **Pneumatics, blowdowns, compressors, leaks (details upcoming)**
  - **Underground storage facilities report 4 of the 6**
  - **Pipeline blowdown reporting added in 2016**
- **Distribution – 6 sources (leaks from mains, services, M&R)**

Transmission Compressor Station

- **Overhead view of example compressor station (Recips & Turbines)**



Subpart W Methane Emission Sources

- **GHGRP: Reporting is required for six methane emission sources for "onshore natural gas transmission compression" sector (*four of six apply to underground storage facilities*):**
  - ***(1) Reciprocating compressor venting*** [A]
  - ***(2) Centrifugal compressor venting*** [A]
  - **(3) Transmission storage tanks (leaking valve)** [A]
  - **(4) Blowdown vent stacks**
  - ***(5) Natural gas pneumatic device venting***
  - ***(6) Equipment leaks from valves, connectors, open ended lines, pressure relief valves and meters*** [B]

  [A] **Subpart W requires direct measurement of emissions for T&S**

  [B] **Subpart W requires Leak Survey for T&S segments; emission estimates based on leak counts & "leaker" emission factors**

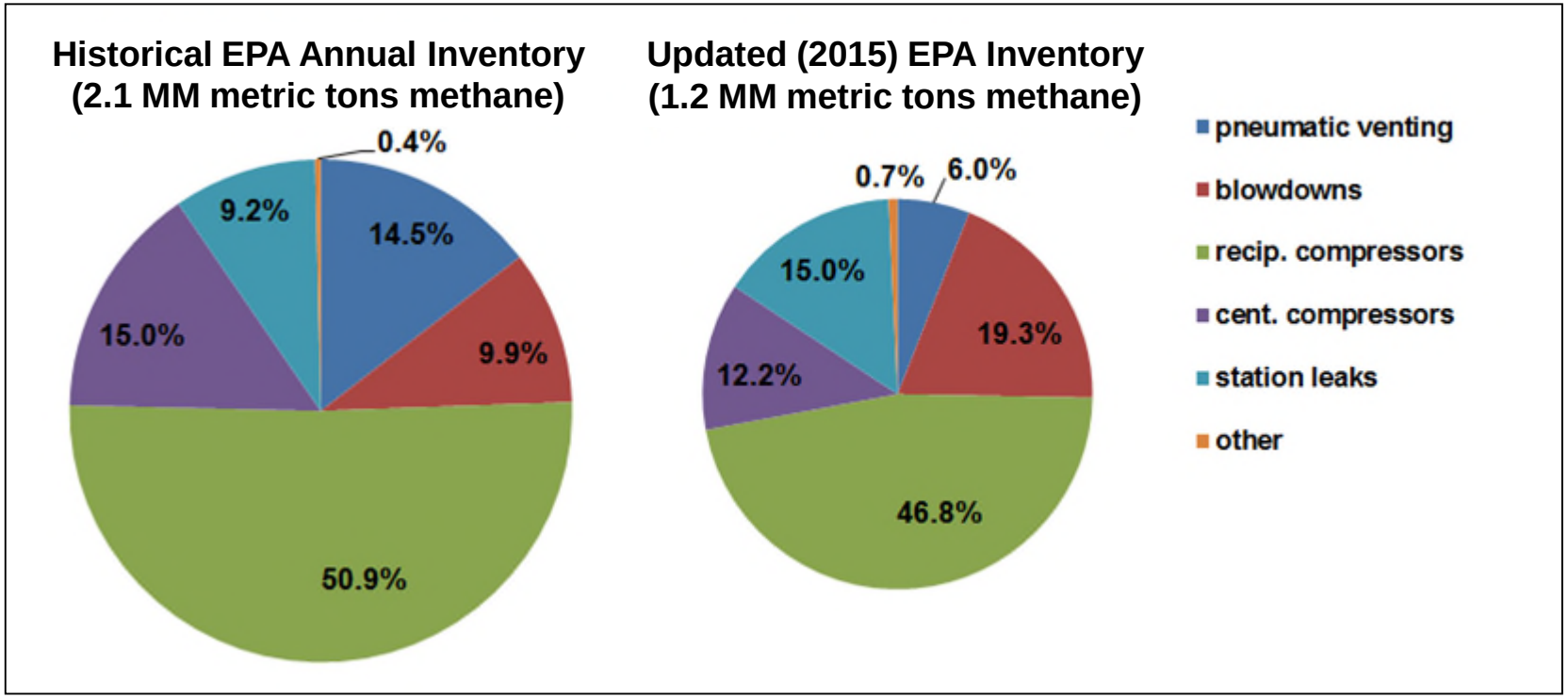
- **Transmission pipeline blowdown reporting added in 2016**

Subpart W Estimation Methods for Natural Gas Transmission

Emission Source	Monitoring Method / Data	Emission Quantification Method
Natural Gas Pneumatic Devices: Low (≤ 6cfh), High (>6 scfh) or intermittent bleed devices	Component Count for (1) Low Bleed, (2) High Bleed and (3) Intermittent Bleed Devices	Population EF (scfh) x device count x 8,760 hr/yr (three emission factors)
Blowdown Vent Stacks	Engineering Estimation (calculation)	Volume calculation; track by event type
Condensate Tanks (leaking dump valve)	Leak Detection & Direct Flow Measurement	For leaks; Measured emission rate x operating hours
Centrifugal Compressors: Blowdown Valve Leaks, Unit Isolation Valve Leaks, and Wet Seal Oil Degassing Vent	Direct Measurement of Vented Gas Emissions in TWO Modes: Operating and Not operating – depressurized	Measured emission rate (or Emission Factor if mode not measured) x operating hrs (by operating mode)
Reciprocating Compressors: Rod Packing Leakage, Blowdown Valve Leaks, and Unit Isolation Valve Leaks	Direct Measurement of Vented Gas Emissions THREE Operating Modes: -Operating, Standby pressurized, Not operating – depressurized	Measured emission rate (or Emission Factor if mode not measured) x operating hrs (by operating mode)
Equipment Leaks (other)	Leak Survey to identify & count leaking components OR Component count (population – for storage wellheads)	Leaking components count x Leaker EF x operating hours OR, Population by component type x EF (storage wellheads)

T&S *Compressor Station* Methane Emissions from Leaks and Vents

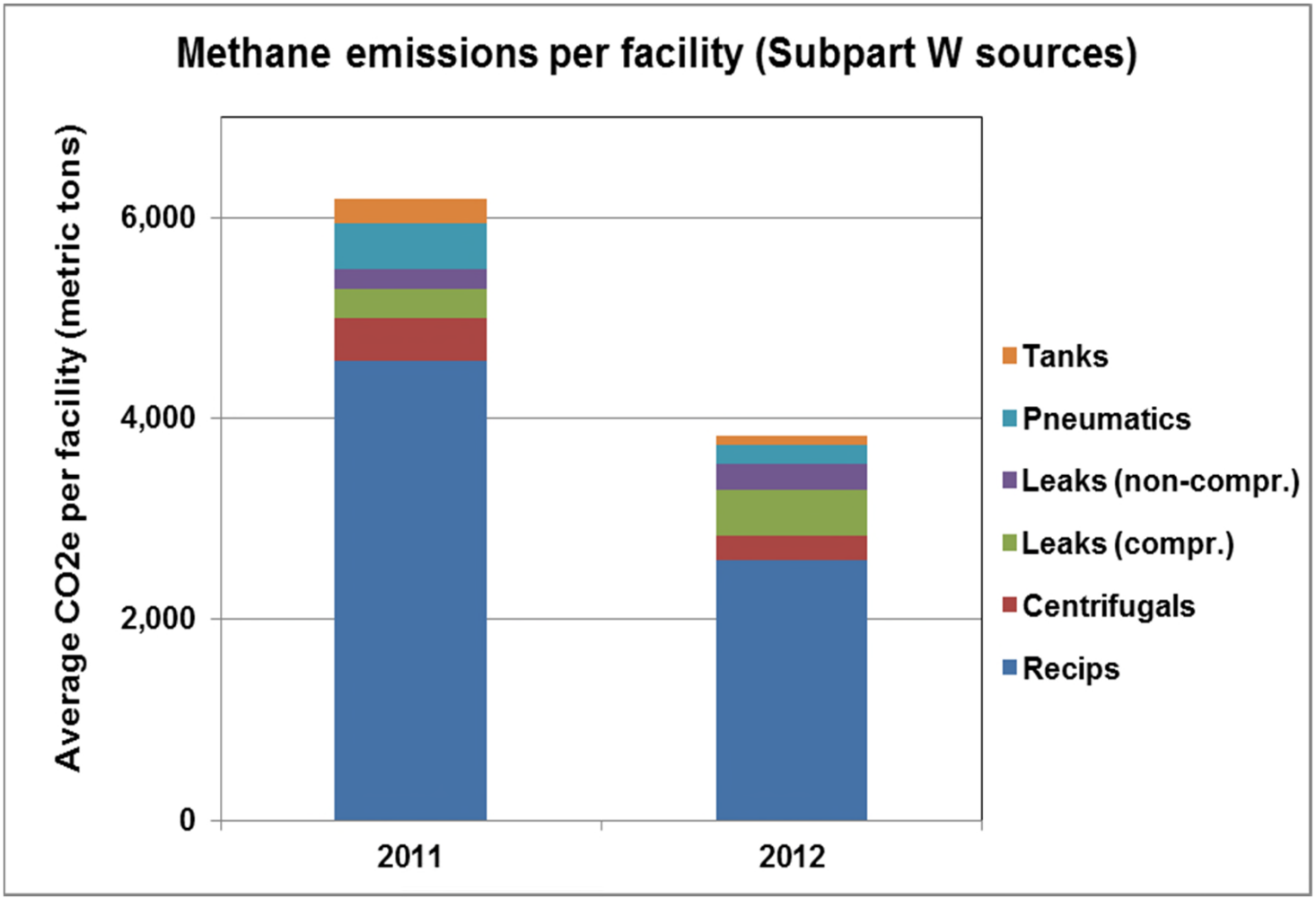
- **EPA updated GHGi methods in 2016 – T&S CH_4 emissions *decreased* using more recent data (e.g., emissions factors from EDF-Industry study)**
  - **The updated estimates did *not* incorporate Subpart W data**
- **Relative % of station emissions from leaks & vents by source type:**
  - **Compressor leaks and rod packing are the primary source**



T & S Methane Emissions: Subpart W Implications

- For many years, estimates in EPA annual GHGi were primarily based on data from mid-1990s EPA/GRI study
  - » Updates in 2016 report (for 2014 inventory) integrated some results from EDF-Industry study (~45 T&S facilities)
  - » Compressor emissions are a key source
  - » Compressor "emission factor" (EF) includes leaks from blowdown valves, isolation valves, rod packing (reciprocating compressor) and seals (centrifugal compressor)
    - These emissions are *measured* for Subpart W of GHGRP
    - EDF-Industry study provided EF updates for compressors
    - Subpart W compressor measurement data provides the opportunity for further review and update of compressor EFs
    - A Pipeline Research Council International (PRCI) report (April 2018) compiled and analyzed Subpart W compressor measurements
- 2nd PRCI report in 2019 will present other Subpart W data

Station Emissions: Subpart W Results for Leaks and Pneumatic Controller Venting



- Bar charts from PRCI GHGRP data compilation

Initial Overview of Emissions Mitigation (and Subpart OOOOa Sources)

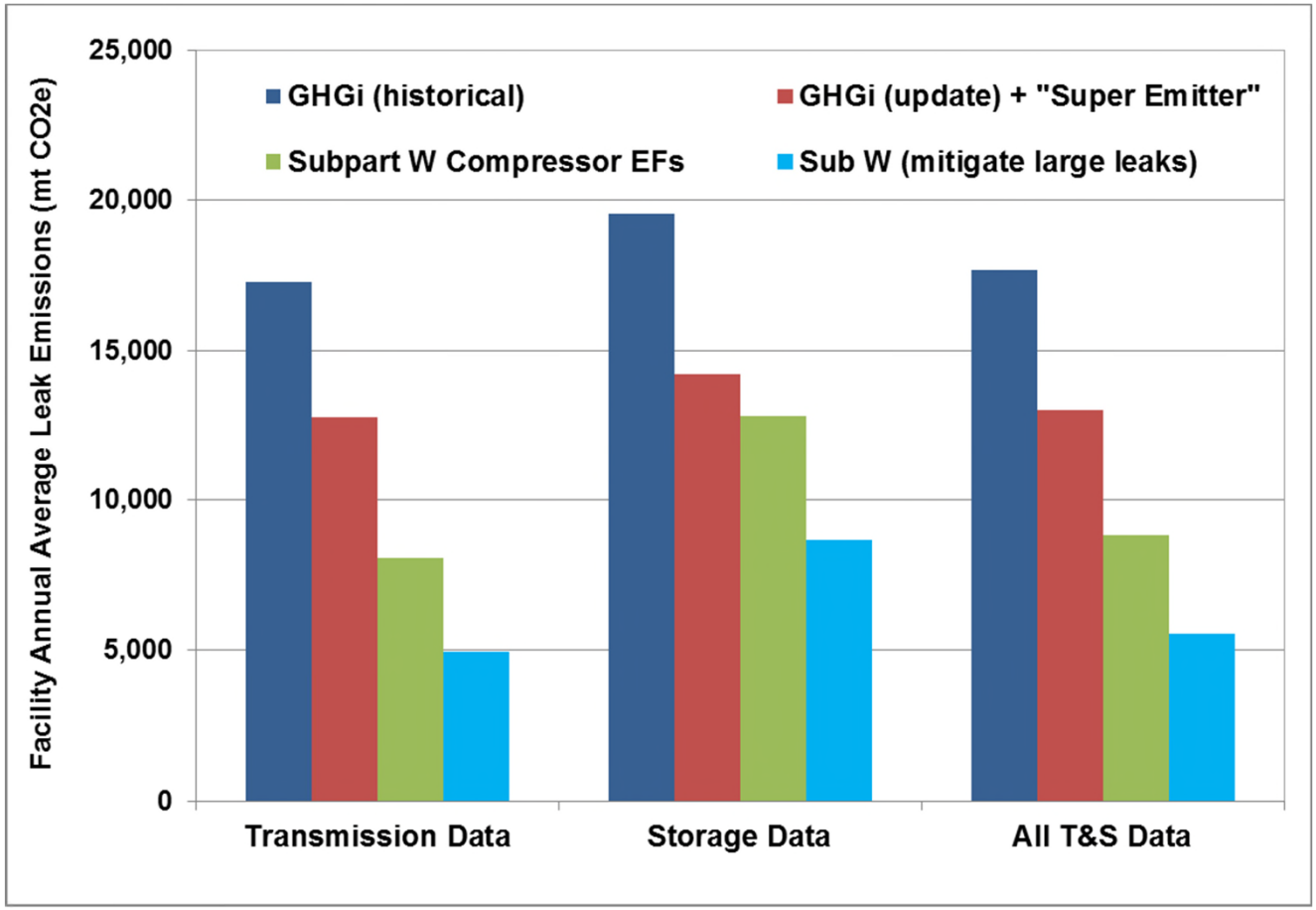
- **EPA National Inventory and Natural Gas STAR reports provided background for 2014 EPA "White Papers" on mitigation of methane from natural gas leaks and venting**
- **T&S sources and mitigation in Subpart OOOOa include:**
  - **Reciprocating compressor rod packing (replacement every 26,000 operating hours or 36 months)**
  - **Centrifugal compressors wet seals oil degassing vents (reduce VOC emissions)**
  - **High bleed pneumatic devices (low / no bleed or air driven devices)**
  - **Equipment leaks (LDAR)**
  - **Storage tanks with VOC emissions >6 TPY (reduce VOC emissions)**

Subpart W Measurement / Survey Data

- PRCI project compiled Subpart W data from members and developed report that presents compressor emission factors
  - » PRCI Report, “GHG Emission Factor (EF) Development for Natural Gas Compressors” (based on over 14,000 measurements)
  - » Report presents 2011–2016 data for different leak source – e.g., unit isolation valves, rod packing, wet seals, etc. and resulting implications for compressor EFs
  - » PRCI White Paper in Spring 2019 will include significant additional details on compressor EFs based on Subpart W data
- PRCI companion report will be available in Spring 2019 that presents other Subpart W data on facility leak surveys, pneumatics, facility and pipeline blowdowns
- These Subpart W results can be compared to historical data (e.g., facility emission estimates based on EPA GHGi)

Updated Compressor EFs: Facility Level GHG Inventory Implications

- **Emission factors can be used to assess the implications for "average" facility leak emissions based on EPA GHGi EFs versus Subpart W-based Compressor EFs**



- **Historical GHGi**
- **Recent GHGi updates w/ EFs from industry-EDF study**
- **Subpart W Compressor EFs**
- **Subpart W Compressor EFs commensurate with mitigating larger compressor-related leaks (~3% of leaks)**

Theme from Literature: Large Leaks are Responsible for Most Leak Emissions

- **INGAA Foundation study summarized literature in response to influx of papers**

http://www.ingaa.org/Foundation/Foundation-Reports/ComparativeMethaneStudies.aspx

Study	Measurement Technique	% of Leak Sources Contribute to...	…% of emissions
Allen (2013)	Direct Measurement of Well Liquids Unloading	44 percent	90 percent
Alvarez (2012)	Analysis of Reported Emissions	10 percent	70 percent
Kang (2014)	Direct Measurement	16 percent	3 orders of magnitude larger than median flow rate
Subramanian (2015)	Direct measurement Site level and concurrent downwind tracer-flux (T&S)	10 percent	50 percent
Mitchell (2015)	Direct measurement at G&P site level; concurrent downwind tracer-flux	30 percent	80 percent
Clearstone (2002)*	Direct measurement w/ Hi-Flow™ sampler	Up to 10 leaks in each facility	36 – 65 percent
NGML, Clearstone, IES (2006)*	Direct measurement w/ Hi-Flow™ sampler and optical methods	0.6 percent	58 percent
Picard (2005)*	Sampling via various methods	Top 10 leaks	80 percent
Shorter (1997)*	Remote sampling via tracer methods	Top emitters	2 – 4 orders of magnitude larger than small emitters
Trefiak (2006)*	Optical measurement and Hi-Flow™	23 percent	77 percent

*** Cited in Brandt (2014), which provided a synopsis of studies and data gaps**

Technology Solutions – Status: Methane Monitoring or Measurement

- **Technology continues to advance – e.g., leak *rate* algorithms may become available for optical gas imaging (OGI)**
- **DOE ARPA-E "MONITOR" program is developing and testing several low cost technologies**
  - **e.g., lower cost OGI / IR technology and operating platforms such as miniature sensors and use on drones**
  - **See https://arpa-e.energy.gov/?q=arpa-e-programs/monitor**
- **OGI / IR camera manufacturers are developing leak rate *quantification* capability using advanced computational algorithms from plume visual; commercial products anticipated**
  - **Even qualitative binning into leak size ranges could support leak repair decisions**
- **While not yet feasible, flexibility to integrate new technologies is desired (e.g., streamlined path for alternative methods)**

Pipeline Blowdown Mitigation

- **Pipeline blowdown mitigation from "pump down" is a common practice, but application is limited**
- **Pipeline blowdown mitigation practices may include:**
  - **Divert to low pressure line: Transfer gas to a parallel line**
  - **In-Line compression: Operate downstream compression after upstream valve is closed**
  - **Mobile compression: Use additional compressors to move gas or pull line down to lower pressure (e.g., incremental gain)**
  - **Flaring: Rarely used**
- **Practice is limited by:**
  - **Availability of parallel line**
  - **Pressures of lines**
  - **Economics (e.g., for mobile compression)**

Summary and Conclusions

- **T&S and Distribution segment methane emissions are a relatively minor contributor to VA methane emissions**
  - **And, some emissions sources are minor for T&S facilities**
  - **Recent data, including Subpart W measurements, show T&S emissions are lower than historical levels**
- **EPA voluntary programs, NSPS, and state actions have focused on similar sources and mitigation approaches**
  - **Voluntary reductions have occurred and will continue**
- **New data and technologies provide the opportunity for program evolution and efficiency gains**
  - **Flexibility / access to alternative methods / technologies**
  - **Addressing large leaks is key – and new technologies may facilitate development of improved approaches**

Questions and Discussion